A Combinatorial Benders' decomposition for the lock scheduling problem

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Ships must often pass one or more locks when entering or leaving a tide independent port or when travelling on a network of waterways. These locks control the flow and the level of inland waterways, or provide a constant water level for ships while loading or unloading at the docks.

We consider locks with a single chamber or several (possibly different) parallel chambers, which can transfer one or more ships in a single operation. The resulting lock scheduling problem consists of three strongly interconnected sub problems : scheduling the lockages, assigning ships to chambers, and positioning the ships inside the chambers. By combining the first two problems into a master problem and using the packing problem as a sub problem, a decomposition is achieved for which an efficient Combinatorial Benders approach has been developed. The master problem is solved first, thereby sequencing the ships into a number of lockages. Next, the feasibility of each lockage is verified by solving the corresponding packing sub problem, possibly returning a number of combinatorial inequalities (cuts) to the master problem.

Experiments on a large test set show that this decomposition method strongly outperforms an existing monolithic approach, especially for instances with a complex packing sub problem. New optimal results for instances with up to 90 ships are generated in less than 12 hours, while a heuristic version of the algorithm generates (near)optimal results for instances with up to 50 ships in less than 10 minutes.

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